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Power Components for the Space Station 20-kHz Power Distribution System

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David D. Renz
Lewis Research Center
Cleveland, Ohio

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POWER COMPONENTS FOR THE SPACE STATION 20-kHz POWER DISTRIBUTION SYSTEM

David D. Renz
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135

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ABSTRACT

Since 1984, NASA Lewis Research Center has been developing high power, high frequency space power components as part of The Space Station Advanced Development program. The purpose of The Advanced Development program was to accelerate existing component programs to ensure their availability for use on the Space Station. These components include a rotary power transfer device, remote power controllers, remote bus solators, high power semiconductor, a high power semiconductor package, high frequency-high power cable, high frequency-high power connectors, and high frequency-high power transformers. All the components have been developed to the prototype level and will be installed in the NASA Lewis Space Station power system test bed.

INTRODUCTION

In the late sixties and early seventies it became apparent that the power requirements of future spacecraft would rise from the present kilowatt level to the hundreds of kilowatt level by the year 2000. The initial space station which is planned for the middle nineties has a projected power level of 75 kW with a growth potential of 300 kW.

A low voltage dc distribution system will not be suitable due to the large conductor weight required to carry the currents. An obvious solution to reducing conductor weight is to raise the operating voltage. Another way to reduce weight is to use a high frequency ac system which decreases both weight and size of magnetic devices such as transformers.

At the beginning of the Space Station Program, NASA performed an extensive power system trade study comparing 150 V dc, 440 V-400 Hz, and 440 V-20 kHz. The conclusion of this trade study was that the 440 V-20 kHz power system was the most efficient, lightest, and lowest in-cost. The study also showed that the 440 V-20 kHz power system had no technical show stoppers but that the 20 kHz component technology was not as fully developed as that of the other power systems.

NASA Lewis has been developing power components for some time that take advantage of both high voltage and high frequency (1). The Space Station Advanced Development program augmented these existing programs and started new ones on an accelerated schedule to ensure that the components would be available for use in the Space Station Power System. The objective of this paper is to summarize the Space Station Advanced Development Program for space power components and provide a comprehensive report.

ROTARY POWER TRANSFER DEVICE

In the early eighties, Sperry Flight Systems developed for NASA Lewis a multihundred kilowatt Roll Ring assembly (2). The Roll Ring is a device that transfers electrical power across a rotating joint through rotating flexures compressed between concentric conductors (Fig. 1). The advantages of the Roll Ring over the slip ring are the elimination of sliding friction and the low torque needed to rotate the device. The Roll Ring can transfer both ac and dc power and has a measured efficiency of 0.9998 (3). There are eight circuits in the assembly (Fig. 2) each capable of conducting 200 A at 500 V dc. This Roll Ring assembly won a 1985 IR-100 award for one of the best new products of that year.

A second Roll Ring assembly was built for NASA Lewis with four circuits (the first assembly had eight circuits) (Fig. 3). The Space Station Advanced Development program redesigned the 4-circuit Roll Ring assembly after evaluation testing (3) to decrease the outgassing time of the assembly and to eliminate possible corona problems. Presently, the Roll Ring is baselined as the Space Station alpha-joint power transfer device. The four circuit Roll Ring assembly is still under going 440 V-20 kHz vacuum testing at NASA Lewis (Fig. 4). The Roll Ring assembly is corona checked every few months during the vacuum life test. Both assemblies have accumulated in excess of 60 Space Station years of rolling time (8-circuit Roll Ring assembly - 64 years, 4-circuit Roll Ring assembly - 114 year) at 100 A or greater (3). Thus far the Roll Ring assemblies have met or exceeded all specifications of the original contract.

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HIGH POWER SEMICONDUCTOR

General Electric Company is presently under contract with NASA Lewis to produce a high voltage MCT (Mos Controlled Thyristor) (4). The MCT under development for NASA Lewis is a 1200 V, 40 A device with a switching time of one microsecond and forward drop of 1 V.

The MCT also requires low gate drive power for turn-off. Figure 5 shows the transistor equivalent, thyristor, and MCT representative schematics (5). The MCT is planned to be used on the Space Station in remote power controllers, main inverters, frequency changers, charge/discharge converters and motor controllers. The MCT with a 1000 V to 40 A rating will be commercially available in the fall of 1988.

HIGH POWER SEMICONDUCTOR PACKAGE

Power Technology Components developed a high power semiconductor package for NASA Lewis (6). This package has low inductance due to the lead configuration and electrically isolates the power chip from the case. The package is hermetically sealed and has an internal coating of parylene (Union Carbide Corp. Trademark) which provides voltage breakdown protection in case the hermetic seal fails (Figs. 6 and 7).

The MCT chip will be mounted in this package and then tested in the various Space Station test bed circuits. Power Technology Components has a commercial version without the parylene coating marketed as their "power mode" series.

REMOTE POWER CONTROLLERS AND REMOTE BUS ISOLATERS

Leach Corporation is developing for NASA Lewis a family of 208 V rms - 20 kHz remote power controllers (RPC's) (5, 10, 25 A) and a family of 440 V rms - 20 kHz remote bus isolators (RBI's) (25, 50, 100 A) (7). The RPC's are current limiting switches that isolate the power distribution system from load faults (8). If a load faults, the RPC switches in a current limiting reactance within 2 μs, limits the fault to 300 percent of the RPC rating and removes the load at the end of this first half cycle of operation (25 μsec). The RPC's will accept on and off commands and current trip point commands. The RPC will supply to the data system the status (on or off), load current, load voltage, sign of the volt-ampere product and the last current reading before tripping. This last current reading will allow time for system failure analysis while protecting the system from overload. The Leach RPC uses parallel FET's for the switching function and has a metal contact relay in series for dead heading the switch. Figure 8 shows an 8-A FET power hybrid module and Fig. 9 shows a 25-A RPC which mounts four hybrid modules on the control card. In the next generation design the Mos Controlled Thyristor (MCT) will replace the FET's.

The remote bus isolators (RBI's) are metal contactors that are used for power bus reconfiguration (7). Under normal operating conditions, they will not be switched under load. Testing at NASA Lewis has shown that they may be switched when current is flowing but this is not desirable. The RBI's will only accept on and off commands. The RBI's will supply to the data system the status (on/off), bus current, bus voltage, sign of the volt-ampere product and the last current reading when power is removed from the bus. This last current reading plus the volt-ampere product will allow for system failure analysis. Figure 10 shows a 100-A RBI without a control card.

POWER CABLE AND CONNECTORS

In 1980, Induction General, Inc. developed for NASA a high power, low inductance, 20 kHz cable (9). The main reason for the low inductance was to reduce the external magnetic field of the cable, it also improved the cable voltage drop and minimized the cross talk between the loads. The cable was constructed as a double sided strip line using straps made of Litz wire (Fig. 11). The Litz wire cable was designed to deliver 25 kW with a 2 percent real loss over 50 m. The Induction General cable parameters were: resistance: 0.83 m-Ω/m, inductance: 0.035 micro-H/m, capacitance: 0.00137 micro-F/m, and weight: 1 kg/m.

The Induction General cable was developed to demonstrate that a low inductance cable was possible. The Litz wire cable showed some problems, such as: very long out gassing times due to gasses trapped in the Litz wire, holding cable configuration constant during the manufacturing process (caused field inductance to increase), not very flexible and fairly heavy. A second generation cable is being made for NASA Lewis by W.L. Gore and Associates, Inc. (10). This cable design uses solid flat foil conductors instead of the Litz wire braid. The foil conductors also were covered with a solid dielectric coating and outgassing will be achieved by using a gas permable dielectric for a filler and outer jacket material. This cable will have approximately the same electrical parameters as the Litz cable, better uniformity during the manufacturing process, but will weigh less and have greater flexibility (Fig. 11).

G&H Technology, Inc. is developing for NASA a 440 V - 20 kHz - 30 kVA connector for terminating the 20 kHz flat foil cable being developed by GORE (11). The connector being designed for NASA Lewis has a voltage drop of 0.375 V at rated current (68 A) and will weigh approximately 1 lb. It is also being designed for handling with space suit type gloves (Fig. 12).

TRANSFORMERS

TRW is developing for NASA Lewis a 440/220, 20 kHz, 25 kVA transformer (12). The wiring schematic of this transformer is shown in Fig. 13. The measured leakage inductance is 1.6 micro-H, which exceeds the specification limit of 3.0 micro-H. The measured efficiency of 99.36 percent exceeds the design goal of 98 percent and the unit weighs approximately 10 lbs. unpotted (Fig. 14). Figure 14 shows the unpotted transformer along with one seven turn secondary. This transformer will be installed in the NASA Lewis Space Station power system test bed for evaluation and system tests.

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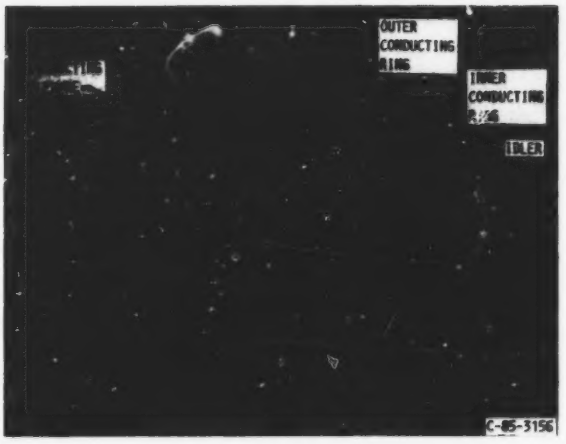

FIGURE 1. - SINGLE ROLL RING CIRCUIT.

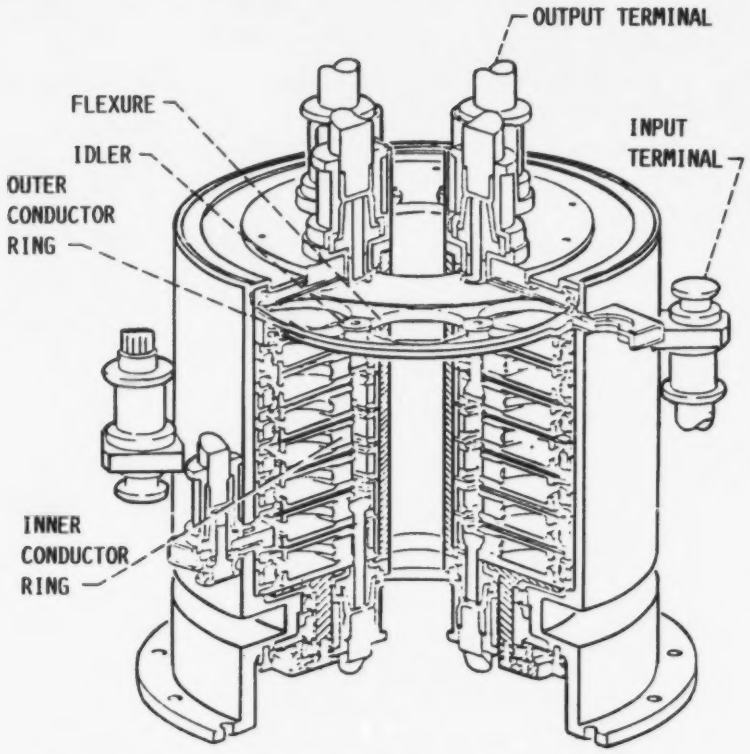

FIGURE 2. - CROSS SECTION OF THE 8-CIRCUIT ROLL RING EVALUATION UNIT.

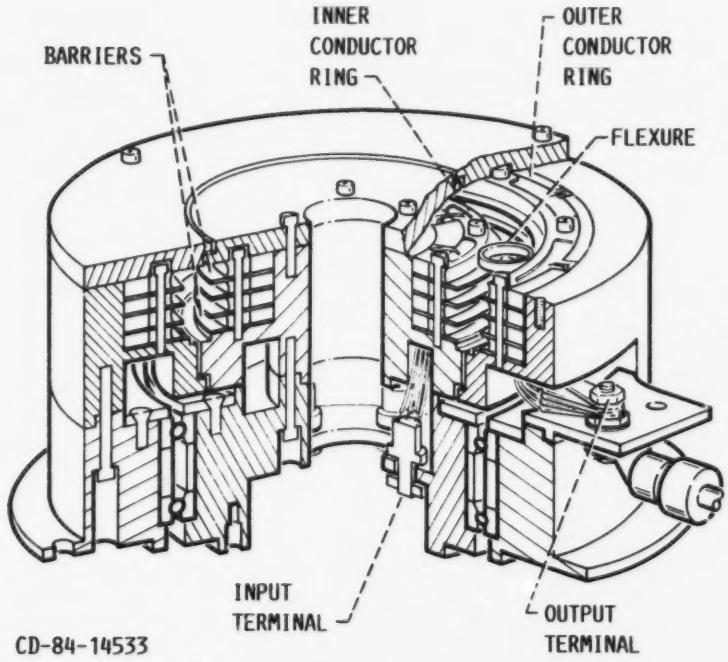

FIGURE 3. - FOUR CIRCUIT ROLL RING ASSEMBLY.

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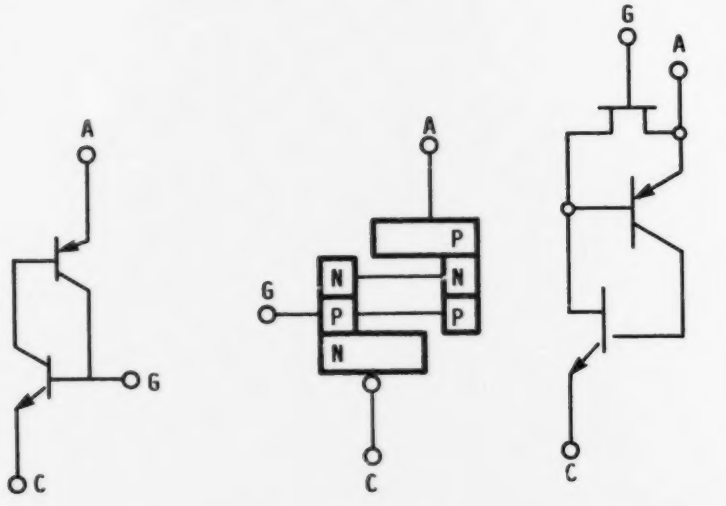
FIGURE 4. - FOUR CIRCUIT ROLL RING ASSEMBLY IN VACUUM TEST



TRANSISTOR EQUIVALENT

THYRISTOR

MOS CONTROLLER THYRISTOR

FIGURE 5. - REPRESENTATIVE SEMICONDUCTOR SCHEMATICS.

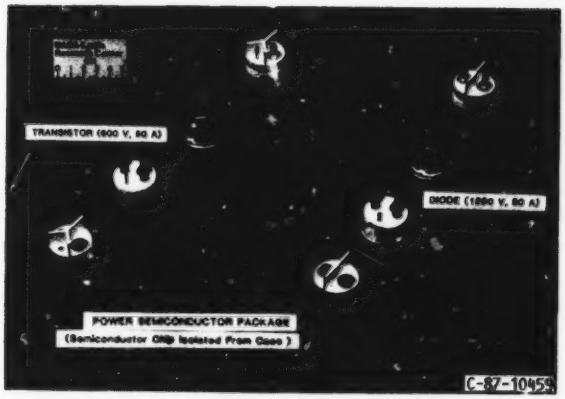


FIGURE 6. - POWER SEMICONDUCTOR PACKAGE

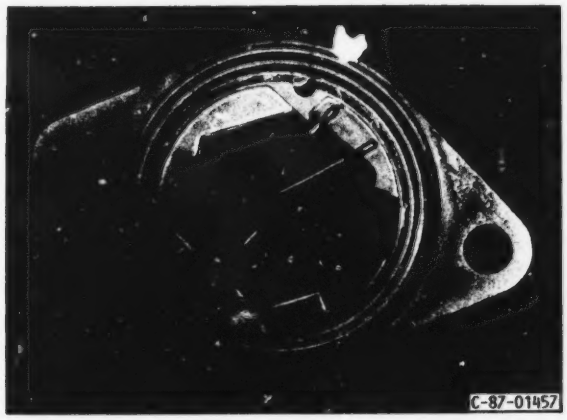


FIGURE 7. - HERMETIC, HIGH POWER SEMICONDUCTOR PACKAGE.

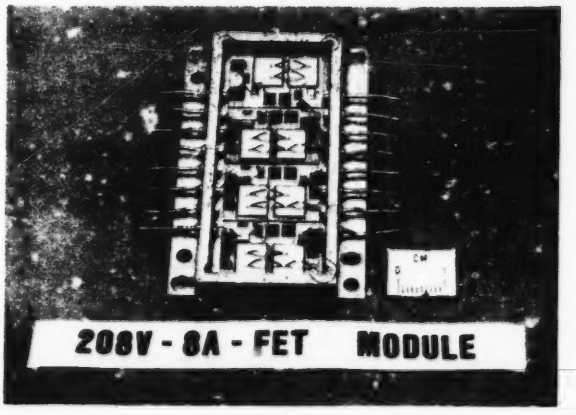


FIGURE 8. - FET POWER HYBRID (8 AMP) MODULE.

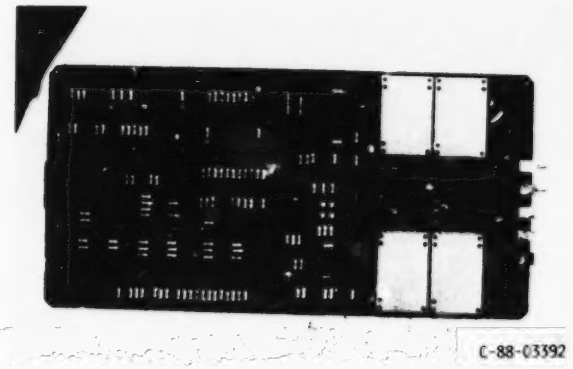


FIGURE 9. - 25 AMP REMOTE POWLR CONTROLLER.

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FIGURE 10. - 100 AMP REMOTE BUS ISOLATOR (NO CONTROL CARD).

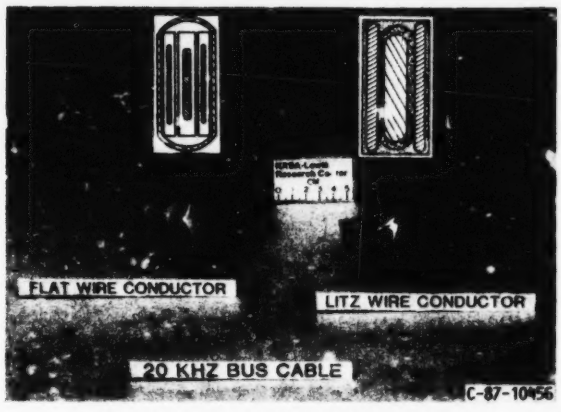

FIGURE 11. - TWO 20 KHz CABLE CONFIGURATIONS.

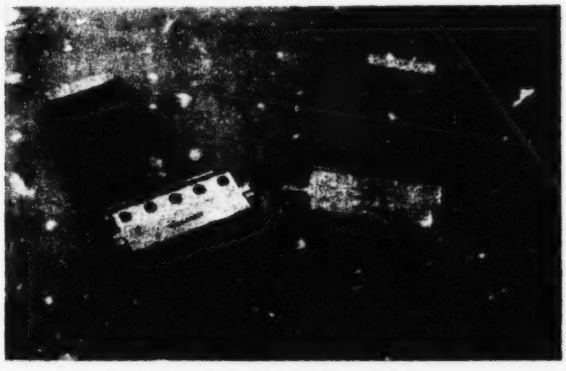

FIGURE 12. - 20 KHz BUS CONNECTOR.

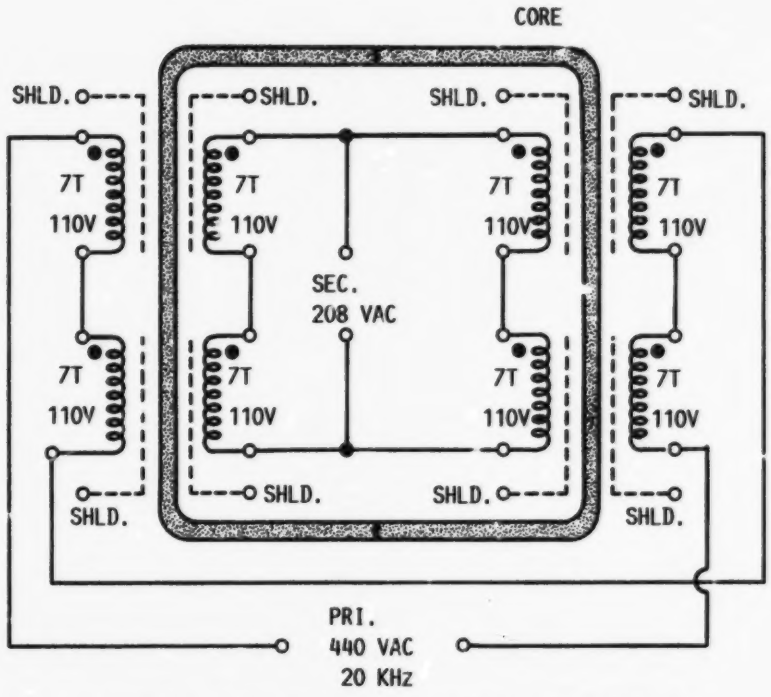

FIGURE 13. - 440/220, 25 KVA TRANSFORMER SCHEMATIC.

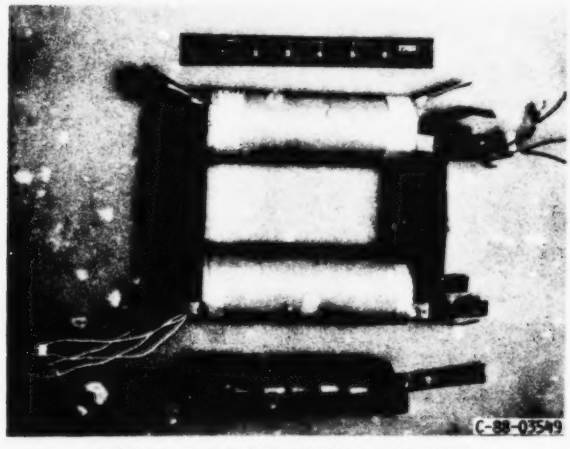

FIGURE 14. - 25 KFA-20 KILOHURTZ TRANSFORMER.

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